S.S. PAPADOPULOS & ASSOCIATES, INC.
ENVIRONMENTAL & WATER-RESOURCE CONSULTANTS

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105
Attention: Mr. Bob Pallarino

STATE OF HAWAII
DEPARTMENT OF HEALTH
P.O. Box 3378
Honolulu, HI 96801-3378
Attention: Fenix Grange, M.S., Program Manager

Subject: Comments on Presentation Materials from the Red Hill Groundwater Modeling Working Group (GWMWG) Meeting #7 and Status of Interim Modeling as Presented Associated with Administrative Order on Consent ("AOC") Statement of Work Requirements 7.1.3 (Groundwater Flow Model Report) and 7.2.3 (Contaminant Fate and Transport Report)

Dear Messrs. Pallarino and Grange:

At the request of the U.S. Environmental Protection Agency ("EPA") and Hawaii Department of Health ("DOH"), collectively the "Regulatory Agencies", I am providing comments and suggestions regarding the status and progress of activities associated with Administrative Order on Consent ("AOC") Statement of Work Requirements 7.1.3 (Groundwater Flow Model Report) and 7.2.3 (Contaminant Fate and Transport Report), emphasizing materials presented at the Red Hill Groundwater Modeling Working Group (GWMWG) Meeting #7, January 11th, 2018.

First, it is important to acknowledge the progress that has taken place in recent months in site characterization, data collection, and the evaluation of those data. The Navy and its contractors have been diligent in their efforts and much good work has been completed. Any evaluation of the potential risk posed by Red Hill fuel storage must be substantiated by extensive, high-quality data and associated analyses and in this context, the progress on data collection and analysis is welcomed. These data and analyses, together with independent information from prior local

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studies and analogous site studies, form the basis for the conceptual site model (CSM) that will underpin subsequent modeling.

In addition, the development of the interim groundwater flow model presented to-date is in many respects of high quality, and consistent with the AOC and the stage of model development. It was particularly encouraging to be recently presented draft particle tracking outputs based upon the current interim groundwater model, which illustrated how the model when further developed can help assess the zones of contribution to water supply shafts as required by the AOC, and provide a basis for the final flow and transport models.

However, based on materials presented to-date, the CSM of Red Hill that is in development by the Navy appears over-simplified in its present form and omits site-specific features and processes that are likely to play an important role in evaluating the risk posed by Red Hill fuel storage to potential receptors including Halawa and Red Hill shafts. Related to this, there are at this time simplifications and in the groundwater model development that parallel the concerns expressed above and below regarding the status of the CSM. While simplifications embodied in intermediate or "screening-level" analyses are often assumed to be *de-facto* protective, the complex conditions at Red Hill offer no guarantee of conservatism via simplification. Given this, the CSM and subsequent model development and analyses should be inclusive rather than exclusive until data and analyses might render undesirable outcomes sufficiently improbable, and where data are absent or site conditions unknown, more conservative (i.e., protective) assumptions should be used.

Specific areas of concern are noted below, together with suggestions to remedy these concerns. Given that G.D. Beckett (AQUI-VER, Inc.) is providing the Regulatory Agencies expertise on the evaluation of Non-Aqueous Phase Liquids (NAPL), the comments below emphasize the overall CSM, and the groundwater flow and contaminant fate and transport models.

1. A priority in the development of the Red Hill CSM to support predictive modeling is a comprehensive 3-D evaluation and documentation of subsurface geologic conditions, emphasizing characteristics that influence flow, transport and fate. The Navy has stated that a 3-D geologic model has been constructed based, in part, on local borings and plentiful if dated barrel logs from Red Hill. When developed to support groundwater flow and contaminant transport models, such a geologic model should incorporate evaluations of unit continuity, bedding and fracture strike and dip, and so on, so that it can be used as the input basis for single or multiphase numerical models. The 3-D geologic model alluded to by the Navy may be detailed (which cannot be independently confirmed), but as noted below presently the geologic underpinnings of the groundwater model are not. Although assurances have been provided by the Navy and its contractors that site-specific features and processes are being considered, they have not been a focus of recent Navy presentations and it is unclear how they are to be quantified, represented, and incorporated into the CSM so that it can underpin groundwater flow and transport modeling. If such has been completed already by the Navy, it should either be presented, or provided for review.

2. The groundwater and NAPL models presented at the GWMWG Meeting #7 currently rest upon the assumption that the complex site geologic conditions can be treated as an equivalent porous media (EPM). This assumption is unlikely to be conservative (i.e., protective), and is not supported by the subsurface geologic data that already exist at and near Red Hill. At this stage of development, and absent data to the contrary, the Red Hill CSM should incorporate a high likelihood of high lateral continuity of features that facilitate flow and transport. Having incorporated these more conservative (i.e., protective) assumptions in the Red Hill CSM and subsequent groundwater and NAPL models, in the event that they result in potentially unacceptable impacts to receptors, field characterization and data collection and testing can then focus on obtaining information to corroborate or refute these conservative assumptions.
3. In regard (2), development of the CSM has not placed sufficient emphasis on features and processes that are likely of significance to the evaluation of risk, but has emphasized other features that are likely to be of less significance. For example, emphasis placed on recharge from the nearby quarry may outweigh its influence on groundwater flow and contaminant transport within underlying basalts. [*During a January 12th meeting at the quarry attended by the Regulatory Agencies, information was provided suggesting that return-flow (non-consumptive use) may be substantially less than presumed.*] As noted above, greater attention should be given to the likely impact of basalt stratigraphy on flow, transport and fate: at this stage of the AOC and development of the Red Hill CSM, it is appropriate to assume that intervening recharge sources and saprolites are not inherently protective until data and analyses can better inform these assumptions.
4. At present, the groundwater model represents major (first-order) Hydrostratigraphic Units (HSUs) – differentiating basalt from saprolite from carbonates, etc. – but does not differentiate within these HSUs (in essence, assuming that the subsurface can be represented as an EPM). Studies from other basalt regions, however, indicate a high potential for connected flow-paths that can enhance the distance and reduce the time for migration versus EPM systems and assumptions. Although few controlled experiments are published for conditions directly analogous to those at Red Hill, studies in simpler environments (such as the Borden site) show that migration is heterogeneous even under ideal conditions. At Red Hill, the documented geology, stratigraphic exposures in the nearby quarry, and variable hydraulic gradients all indicate that the subsurface is more complex than the Navy's current CSM and groundwater model represent.
5. The upgradient (i.e., northeastern, mountain-front) boundary condition of the groundwater flow model may exert a strong influence on flow and migration patterns, acting to enhance or possibly over-prescribe the propensity for flow to occur "*Mauka to Makai*" regardless of other factors such as recharge rates and pumping. This boundary condition (in concert with the lateral boundaries) should be viewed with caution and evaluated via calibration-constrained sensitivity analyses. This was perhaps highlighted by the water budget analysis

presented at the GWMWG Meeting #7 in part because spring flow was assumed to be low in 2015 at time of relatively high recharge which seems counterintuitive and suggests that the assumption of constant inflow along the mountain-front boundary may be erroneous.

6. Although instructive as an introduction to and illustration of relevant concepts and terms, the NAPL evaluation presented at the GWMWG Meeting #7 appears to be simplified and of uncertain or limited future application. The calculations appear to suggest little to no potential for groundwater impact, whereas the converse appears to be demonstrated by available data. The Navy NAPL evaluation will require substantial revision or enhancement to provide utility in the ongoing evaluation of NAPL migration and associated risk.

7. With regard to transitioning from an interim sub-regional groundwater flow model to detailed analyses of contaminant fate, transport, and associated risk: while the work presented at the GWMWG Meeting #7 is being performed in the context of interim model development in accordance with the AOC, the approach may not yet be sufficiently comprehensive to inform tank upgrade decisions or evaluate risk. Recognizing that models are imperfect representations of the world, simplifying assumptions used to-date in the development of the Red Hill CSM and the groundwater flow model could lead to over-simplified fate and transport analyses. To remedy this, the Navy should present the technical approach(es) under consideration to represent the complex subsurface conditions in the Red Hill CSM and derived flow and transport models. A wide range of possibilities exists: for example, when considering zones of contribution to water supply shafts, the use of advective-dispersive rather than solely advective pathline transport can be instructive. Subsequently, the dual domain formulation (5,6,7) may be suitable for initial mass-conservative transport simulations as an alternative to discretizing the flow model at the scale of connected conductive features, although the MODFLOW-USG code selected by the Navy is ideally-suited to refinement in areas of interest and structure-imitating methods could be used to represent and parameterize the basalt geology. Whatever approach the Navy ultimately adopts to represent greater site-specific hydrostratigraphic and transport detail, the developed models must support realistic flow, transport, fate and risk analyses. As the development of the interim model nears completion, the Navy should present an evaluation of the appropriate scale for discretizing the groundwater flow and contaminant transport and fate models to adequately represent field conditions.

Given the requirements of the AOC, the intended applications of the groundwater flow and fate and transport models to evaluate scenarios and risk, and the reliance of these analyses on a site-specific Red Hill CSM, it is likely that the models will combine locally-detailed (and finely discretized) but regionally-simplified parameterization and discretization so that sensitivity and predictive analyses can be used to evaluate whether there are conditions that are consistent with the data under which an unacceptable impact can occur to potential receptors. The CSM and derived models will over time benefit from further data collection that can help confirm or refute

underlying conservative assumptions implemented to provide for protectiveness. Whether and to what extent additional characterization may be necessary is presently difficult to gage without understanding to what extent existing data have been incorporated into the Red Hill CSM and derived models. If the CSM and derived models incorporate features and processes at appropriate scales, then the necessity for and extent of any additional characterization may be informed via calibration-constrained sensitivity and predictive analysis. If the CSM and derivative models are, however, too simplified, then the models will not provide the benefit to the project that they may be capable of.

Overall, while the progress made by the Navy and its contractors is encouraging, and it is recognized that development of a comprehensive CSM and derivative predictive models must of necessity follow a systematic process of steadily incorporating site-specific complexity, at this time the Red Hill CSM appears over-simplified and not sufficiently inclusive of site-specific subsurface complexities.

Please feel free to contact me if you have any questions regarding the foregoing concerns.

Sincerely,

S. S. PAPADOPULOS & ASSOCIATES, INC.

Matthew J. Tonkin
President

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(4) July 2017, Final. Second Quarter 2017 - Quarterly Groundwater Monitoring Report Red Hill Bulk Fuel Storage Facility. Joint Base Pearl Harbor-Hickam, O'ahu, Hawai'i. DOH Facility ID No.: 9-102271, DOH Release ID Nos.: 990051, 010011, 020028, and 140010.

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